

Variability of the seeds and cones and key taxonomic characters selection of *Larix* in Northeast China¹⁾

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Abstract The paper presents the results of biometrical study of the seeds and cones of larch taxa from Northeast of China. Fourteen characters are considered and their analyses showed that the seeds and cones of the larch taxa were relative greatly variable. Cluster analysis and principal component analysis for all 6 larch taxa were made. The analysis results proved that the dominant larch population in Toudao Farm fell within the range of variation of *Larix olgensis*. The key taxonomic characters are the length of seed wing, length of cone, length of seed, the length/width ratio of seed and number of scales.

Key words: *Larix*, Seeds and cones, Variability, Biometry, Key character selection, Principal component analysis, Northeastern China

Introduction

Larix olgensis Henry and *Larix gmelinii* (Rupr.) Rupr. are both the native tree species in China, but their distributing centers are not within the range of China. *Larix olgensis* is mainly distributed in North Korea and adjacent Northeast China and Russia (Dylis 1961). In China, its distributing center is in the Changbai Mountains. Nevertheless, *Larix gmelinii* is mainly distributed in the Far-East and East Siberia of Russia and Northeastern China. Its distributing center in China is in the Daxing'an Mountains. The characters of the sexual reproduction organs such as the seeds, cones and flowers are generally relative stable and often used in the taxonomy. In this paper, we selected 14 taxonomic characters of seeds and cones and carried out cluster analysis on the 6 local taxa of larch from Northeast China, including a dominant taxon from Toudao Farm. Moreover, the principal component analysis method is firstly used to the key taxonomic character selection. The work may provide important reference for classification study of larch in this region.

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Materials and Methods

Six localities were chosen for seed and cone samples. Each sample consists of 30 seeds and 30 cones collected at random from the ground at the base of the respective trees. Analyses of the seeds and cones are based on 14 characters, nine of which are metric, and five cephalometric. These characters are as follows:

- A--length of cone;
- B--width of cone;
- C--length/width ratio in a cone;
- D--number of scales;
- E--length of cone/number of scales ratio;
- F--length of scale;
- G--width of scale;
- H--length/width ratio in a scale;
- I--length of seed wing;
- J--width of seed wing;
- K--length/width ratio of a seed wing;
- L--length of seed;
- M--width of seed;
- N--length/width ratio of seed.

In order to show the differences and similarities between all six samples, the clustering analysis method was adopted. Meanwhile, principal component analysis method was applied to the key taxonomic character selection.

Materials for the study were collected by the

Received: 1998-10-14

¹⁾This research was supported by Natural Science Foundation of Heilongjiang Province.(C9515)

authors from the following localities: (1) Toudao Forestry Farm, Heilongjiang Chaihe Forestry Bureau (TD); (2) Dahailin Forestry Bureau (DH); (3) Tuqiang Forestry Bureau, Daxingan Mountains (DT); (4) Suiyang Forestry Bureau (SU); (5) Xiaobeihi, Dongjingcheng Forestry Bureau (DX); (6) Changbai Mountains (CB). All materials were collected from the natural larch trees, except that for Toudao taxon. The materials from Toudao is a new found artificial population and has a fast-growing character.

Results and Analyses

Variability of seeds and cones

Variability of the characters of seeds and cones of larch taxa from Northeast China are described on the basis of the biometric method. The most significant statistical data are presented in Table 1.

From Table 1, we can see that the various charac-

ters of seeds and cones present relative great variability. Variation coefficients (CV) range from 0.060 2 in width of seed to 0.2837 in length/width ratio of seed. Among these characters, length/width ratio of seed (N), length/width ratio in a cone (C), length of seed wing (I), number of scales (D) and length of cone/number of scales (E) have a greater variability, width of seed (M) and width of scale (G) have little variability, and the width of cone (B), length/width ratio in a scale (H) and width of seed wing (J) have a medium variability.

Differentiation of the local samples

Differences between the local samples of seeds and cones of larch taxa are shown in Table 2 and 3, in which arithmetic means and the ranges (min., max.) of characters from A to N of seeds and cones for local samples were listed

Table 1. Ranges (Min., Max.), arithmetic mean (M) with standard error (SE), standard deviation (SD) and coefficient of variation (CV) of the characters of seeds and cones for larch taxa from Northeast China

Characters	Min.-Max.	M±SE	SD	CV
A	10.20-34.00	21.12±0.28	2.82	0.1335
B	11.54-28.20	18.73±0.39	3.88	0.2072
C	0.79-1.70	1.25±0.03	0.32	0.2560
D	15.00-48.00	28.50±0.68	6.75	0.2370
E	0.44-1.42	0.77±0.02	0.18	0.2341
F	6.14-16.20	11.38±0.23	2.31	0.2030
G	6.30-13.80	9.00±0.08	0.84	0.0937
H	0.99-1.80	1.26±0.02	0.15	0.1203
I	5.02-13.60	9.34±0.23	2.30	0.2459
J	2.32-5.06	3.64±0.05	0.53	0.1447
K	1.97-3.87	2.57±0.05	0.51	0.1971
L	2.38-5.94	4.19±0.07	0.74	0.1762
M	1.96-3.94	2.60±0.02	0.16	0.0602
N	1.01-2.40	1.74±0.05	0.49	0.2837

Table 2. Arithmetic means of characters of seeds and cones (A-N) from the local samples of larch taxa in Northeast China

Characters	Regional sample average	Local samples					
		TD	DH	DT	SU	DX	CB
A	21.12	22.58	25.60	21.71	17.53	19.67	19.61
B	18.73	20.94	24.69	15.32	14.54	20.06	16.80
C	1.25	1.08	1.04	1.42	1.21	0.98	1.16
D	28.5	31.55	39.15	19.45	24.20	26.75	29.90
E	0.77	0.72	0.65	1.12	0.73	0.74	0.66
F	11.38	12.00	12.92	14.66	8.73	11.05	8.92
G	9.00	9.68	9.32	9.92	7.86	9.14	8.09
H	1.26	1.23	1.39	1.48	1.11	1.21	1.10
I	9.34	9.59	12.49	11.32	7.04	8.88	6.70
J	3.64	4.28	3.57	4.11	3.03	3.82	3.05
K	2.57	2.24	3.50	2.75	2.32	2.32	2.20
L	4.19	4.81	5.28	3.92	3.28	4.17	3.69
M	2.60	2.52	2.58	2.57	2.41	2.62	2.88
N	1.74	1.91	2.05	1.53	1.36	1.59	1.28

The cones of larch are generally ovate oval or long-ovate, but there exist great variations between the local samples. Among these taxa from Northeast of China, the cones sample (taxon) from Daxing'an Mountains are the longest and thinnest, and that from Xiaobeihu is the shortest and thickest.

Scale number of a cone from Daxing'an Mountains is 19.45 in average. And that from Dahailin, Toudao and Changbai Mountain taxa averages 39.15, 31.55 and 29.90 separately. For the character of scale length, the taxon from Daxingan Mountains has the longest scale. Its length averages about 14.66 mm. The taxa of Changbai Mountains and Suiyang have the shortest scales and their scale lengths average only 8.92 mm and 8.73 mm respectively. The scales become shorter from north to south in Northeast China. The cone scale from Daxing'an Mountains is also the widest, with an average of 9.92 mm. The

scales of taxa from Changbai Mountains and Suiyang are thinnest, with an average width of 8.09 mm and 7.86 mm respectively. Thus we can conclude that the cone scale in Daxingan Mountain taxon is bigger than that of taxa from Changbai Mountains and Suiyang. The scale sizes of larch taxa also present a trend changing smaller from north to south in Northeast China. From the analyses of length/width ratio of a scale, we can see that the taxon in Daxingan Mountains has thinner and longer scales. The taxa in Changbai Mountains and Suiyan have wider and shorter scales. The taxa in Daxing'an Mountains and Dahailin have longer seed wings, with an average length of 11.32 mm and 12.49 mm respectively. On the other hand, the taxa in Changbai Mountains and Suiyan possess shorter seed wings, and their length of seed wing is only 6.7 mm and 7.04 mm respectively.

Table 3. Ranges (min., max.) of the characters from A to N of the seeds and cones for the local samples of larch taxa in Northeastern China

Characters	TD	DH	DT	SU	DX	CB
A	17.46-34.00	20.96-30.80	20.00-23.80	15.10-19.00	10.20-24.86	15.60-23.78
B	17.76-24.52	20.06-28.20	12.70-18.90	11.54-18.56	17.40-26.22	13.28-19.90
C	0.86-1.42	0.91-1.17	1.24-1.70	1.03-1.45	0.79-1.40	0.99-1.61
D	22.00-41.00	32.00-48.00	15.00-23.00	17.00-33.00	17.00-41.00	24.00-40.00
E	0.55-0.95	0.53-0.83	0.92-1.42	0.58-0.93	0.44-0.92	0.51-0.74
F	10.70-13.52	11.00-14.50	13.40-16.20	6.90-11.00	6.14-14.12	7.36-9.94
G	8.54-10.54	8.24-10.22	8.74-13.08	6.78-9.94	6.30-10.16	7.00-9.60
H	1.08-1.38	1.24-1.65	1.12-1.80	1.00-1.31	1.46-0.97	0.99-1.26
I	8.24-11.64	10.96-13.60	9.70-12.40	5.02-9.80	7.88-10.54	5.96-7.74
J	2.70-5.06	3.06-4.00	3.28-5.00	2.32-3.82	2.86-4.52	2.70-3.40
K	1.98-2.58	3.19-3.87	2.09-3.25	2.08-2.99	1.98-2.60	1.97-2.83
L	4.10-5.94	4.08-5.80	3.50-4.40	2.38-4.00	2.52-4.88	3.04-4.30
M	2.12-3.08	1.98-2.90	2.10-3.60	2.02-3.06	1.96-2.88	2.04-3.94
N	1.56-2.40	1.94-2.30	1.17-2.09	1.03-1.74	1.29-1.84	1.01-1.84

In addition, by analyzing the change ranges of the seed and cone characters of various taxa, it can be proved that the cone length of Toudao taxon has the greatest variation, and the Daxing'an Mountains taxon has the smallest changes in cone length. Meanwhile, the taxon from Daxing'an Mountains also has the smallest variation in number of scales, seed length and width of seed scale.

Similarity of the larch taxa in Northeast China

System cluster analysis was adopted to analyze the similarities of 6 larch taxa. We selected 14 taxonomic characters (A~N). Using their mean values of each taxon, the 6×14 data matrix (see the right part of Table 2) was built. By taking the smallest distance program of cluster analysis, we can obtain the average distance of each two taxa. Based on the value of average distance, the most similar taxa can be clustered together. According to the clustering results, we

analyzed the relationships of all 6 taxa and built systematic tree (see Fig. 1).

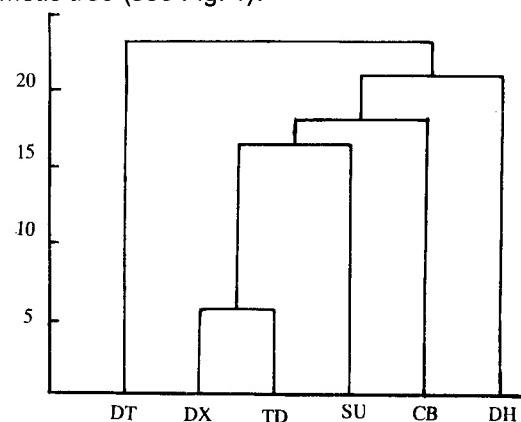


Fig. 1. Systematic tree of larch taxa from Northeast China

The clustering results indicated that of taxa from DX

(Xiaobeihu, Dongjiancheng Forestry Bureau) and TD (Toudao Forestry Farm, Chaihe Forestry Bureau) have the closest relationship, with an average distance of 5.521 4. The average value of distance from taxon of SU (Suiyang Forestry Bureau) to the cluster of DX and TD is 16.046 8, from CB (Changbai Mountains) taxon to the cluster (including DX, TD and SU) 17.619 3, from DH (Dahailin Forestry Bureau) to the cluster of DX, TD, SU and CB is about 20.441 7. The distance value from DT (Daxing'an Mountains, Tuqiang Forestry Bureau) to other taxa is the greatest, and the average value of distance reached up to 22.689 5. When we draw a line at the value of 20.4417, the taxa in this region can be clearly divided into two clusters. One is the taxa from DX, TD, SU, CB and DH, and the other is DT. According to the taxonomic characters and distributing regions, the taxa from DX, TD, SU, CB and DH are within range of *Larix olgensis* species and the taxon from DT is *Larix*

gmelinii species. This analysis results presented that *Larix gmelinii* had a relative far distance with *Larix olgensis*. Meanwhile, if DX taxon is *Larix olgensis* var. *heilengensis*, the TD artificial population may be the same taxon.

Key taxonomic characters selection

We first use the principal component analysis (PCA) to select the key characters for the larch taxa classification. In this method, we adopt R-type analysis to find synthetically variable Y and omit the principal component with lower variance, then the principal component with higher taxonomic values can be obtained. Finally, we can select key taxonomic characters from the principal components which have higher taxonomic values. Thus, the characters that are key to larch taxa classification were obtained. The analysis results are listed in Table 4.

Table 4. Principal component analysis for the 14 taxonomic characters of *Larix* taxa in Northeast China

Characters	1st Principal Component (Y ₁)		2nd Principal Component (Y ₂)		3rd Principal Component (Y ₃)		4th Principal Component (Y ₄)	
	Latent Vector	Loaded Values						
X ₁	0.3383	0.9391	-0.0984	-0.1851	0.1911	0.2414	0.0191	0.0193
X ₂	0.2781	0.7719	-0.3159	-0.5940	-0.0430	-0.0543	0.1723	0.1738
X ₃	-0.2027	-0.5625	0.0744	0.1400	0.6266	0.7915	-0.0006	-0.0007
X ₄	0.1746	0.4847	-0.4578	-0.8609	0.0836	0.1056	-0.0353	0.0356
X ₅	0.0519	0.1440	0.5192	0.9763	0.1010	0.1276	-0.0960	-0.0968
X ₆	0.3014	0.8365	0.2820	0.5303	0.1062	0.1342	0.0311	0.0314
X ₇	0.2977	0.8265	0.2412	0.4535	-0.0234	-0.0295	0.3295	0.3323
X ₈	0.2862	0.7943	0.2810	0.5283	0.1852	0.2340	-0.1847	-0.1863
X ₉	0.3461	0.9607	0.1013	0.1905	0.0808	0.1020	-0.1665	-0.1679
X ₁₀	0.2408	0.6684	0.2539	0.4774	-0.1937	-0.2446	0.5071	0.5114
X ₁₁	0.2822	0.7833	0.0613	-0.1153	0.2203	0.2782	-0.5329	-0.5374
X ₁₂	0.3266	0.9066	-0.1970	-0.3704	-0.0101	-0.0128	0.1922	0.1939
X ₁₃	-0.0836	-0.2319	-0.1353	-0.2544	0.6419	0.8108	0.4290	0.4326
X ₁₄	0.3186	0.8843	-0.2317	-0.4357	-0.0318	-0.0402	-0.1613	-0.1626
Latent roots	7.7044		3.5362		1.5956		1.0171	
Contribution rate(%)	55.0314		25.2584		11.3969		7.2152	
Accumulative contribution rate(%)	55.0312		80.2896		91.6865		98.9517	

Based on latent roots, contribution rate and the accumulative contribution rate, we chose the first four principal components. Their accumulative contribution rate is high up to 98.9517%, and lost information value is very small, only about 1.048 3%. In the first principal component(Y₁), the loaded values of the seed wing length, cone length, seed length and the length/width ratio of seed are relative higher. These characters have important values to the larch taxonomy. In the second principal component(Y₂), the character of the length/width ratio of cone, number of seed scales and cone width have high loaded values,

so they also have relative important roles in the larch classification. In the third and forth principal components, the characters of the length/width ratio of cone and the length/width of seed wing have relative high loaded values, but for their contribution rates are lower, so that their taxonomic effects of these characters may be declined. Thus it can be seen that principal component analysis gave us a valid method to draw key characters in taxa classification from the former principal components. In the larch taxa analysis, the characters of seed wing length, cone length, seed length, length/width ratio of seed, scale number

and length/width ratio of cone are the key taxonomic characters.

Conclusions

1. The seeds and cones of larch taxa in Northeast China have a relative greater variability.
2. The seed and cone characters of *Larix gmelinii* from Daxing'an Mountains are more stable than that of *Larix olgensis* from other localities.
3. The length and width of the seed scale of the taxon from Daxingan Mountains are greater than that of taxa from Changbai Mountains and Suiyang. The scale size presents a trend changing smaller from north to the south in Northeast China.
4. The seed scale of taxa is thinner and longer in the North, and wider and shorter in the south of this region.
5. The seed wing in northern part is longer than that in the south of Northeast China.
6. The taxon of Daxingan Mountains (*L. gmelinii*) has smaller changes in cone length, seed length and width of scale than that of other 5 taxa in the south (*L. olgensis*).
7. The Toudao artificial population is within the range of *Larix olgensis* species, and belongs to *L. olgensis* var. *heilinensis*.
8. The principal component analysis is a valid method to the key taxonomic characters selection. In this study, seed wing length, cone length, seed length, the length/width ratio of cone, seed scale number and the length/width ratio of cone are the key taxonomic characters to the larch taxa classification.

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(Responsible Editor: Chai Ruihai)